Analysis of Emerging Mote Technology as a Distributed Sensor Platform

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This project was a single year effort to investigate the potential benefits and applications of an emerging technology referred to as *motes* (or more accurately *macro motes* (Figs. 1-3), given current achievable sizes with commercial off-the-shelf components). Motes are small, inexpensive, low-power devices that can automatically form *ad hoc* wireless communication networks among themselves when deployed in an indoor or outdoor environment. When sensors are connected to their I/O ports, motes become a quick and cost effective platform for distributed sensing applications.

The motes themselves have embedded networking and routing code, which allows them to support various network topologies, from simple star patterns to more complex multi-hop mesh and partial mesh networks. Typically powered by one or two small batteries, motes operate with low-duty cycles, and *sleep* the majority of the time to conserve battery life. They awake only when a sensor reading is to be transmitted or when a command or message from another mote is to be received.

The basic components of motes include a battery power source, a micro-controller, an RF transceiver, one or more analog-to-digital channels, and one or more digital I/O channels. Communication, applications, and management software can be preprogrammed into the mote or written by the user. Motes typically transmit at the 1-mW power level and achieve 20 m to 100 m distance, depending on antenna configuration and the RF propagation characteristics of the environment in which they are deployed.

Mote technology began as a DARPA-sponsored "smart dust" project that envisioned miniature MEMS-based devices on the order of 1 mm^3 in size with an integrated solar cell, thick film battery, analog sensor(s), a small processor, and optical transceiver. Work toward that goal continues, with 100-mm^3 prototypes created and tested. Currently, however, a trend to produce larger *macro mote* devices using inexpensive commercial components has emerged. Companies are producing third generation products and others have created mote evaluation kits for customers to
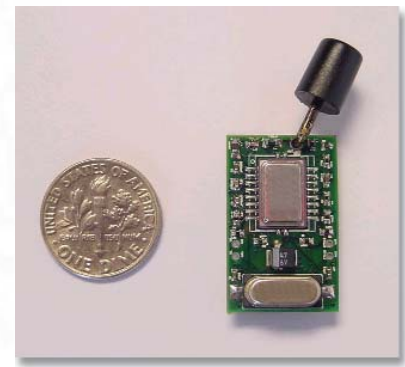

Figure 1. (Left) iBean wireless mote monitoring heat pump current draw; (right) iBean unpackaged mote next to dime for size comparison.

conduct inexpensive testing and prototyping. There is also an open source software environment available for motes (Tiny OS), that includes an operating system, distributed database system, routing algorithms, and various programs for distributed sensing applications. Users can modify the code as necessary or create their own custom applications using the nesC programming language, an open source language developed for the mote technology.

Project Goals

The project goals were to characterize the current capabilities of macro mote technology offerings in terms of performance, functionality, sensor integration, power management, and system management; perform a cyber security analysis of mote networks and create security policy guidelines for wireless mote technology; gain first-hand knowledge and experience with macro motes through indoor and outdoor pilot implementations in the areas of environmental monitoring and building automation applications; and work to introduce mote technology and explore potential uses of motes to meet LLNL programmatic objectives.

Relevance to LLNL Mission

Motes may be good candidates to replace or augment current manual or expensive monitoring applications at LLNL, such as groundwater or surface water monitoring, environmental testing for contaminants, and energy management. Other potential applications include security, device tracking, and chemical/biological/radiation sensing systems.

FY2004 Accomplishments and Results

In this fiscal year, we have conducted security vulnerability analysis of mote networks and created guidelines regarding their use and deployment at the Laboratory; characterized the performance, reliability, and sensor integration features of several mote technology offerings; and performed system integration of mote hardware, sensors, and software to implement several prototype mote networks. The networks include: a 12-node outdoor mote pilot network to interconnect ground well monitoring locations; a 17-node indoor/outdoor mote network to monitor building environmental conditions and HVAC equipment parameters; and a 10-node indoor standards-based mote network compliant with the IEEE specification for this technology.

Related References

1. "Smart Dust: Mighty Motes for Medicine, Manufacturing, the Military and More," http://www.nwfusion.com/nltechexec350, 2003.
2. "Smart Dust Project: Autonomous Sensing and Communication in a Cubic Millimeter," http://robotics.eecs.berkeley.edu/~pister/SmartDust/
3. Collection of Links to Wireless Sensor Network Research and Design Topics: http://www.research.rutgers.edu/~mini/sensornet works.html

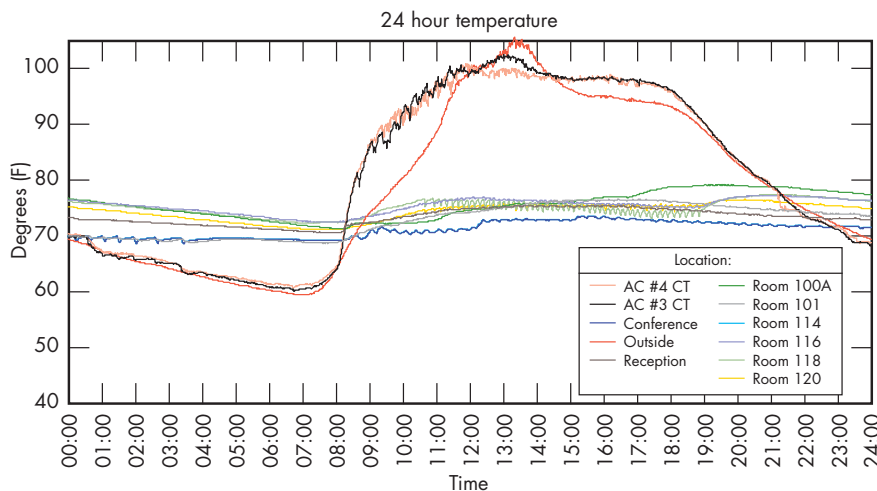Figure 3. Repackaged dust sensor with integrated pressure transducer on top of ground well.

Figure 2. Data from software written to collect and graphically display temperature readings for the indoor/outdoor building monitoring mote network.